V

VITAMIN C

THE discovery and colonization of America by dauntless explorers from Europe in the fifteenth and sixteenth centuries did not result in the anticipated inflow of spices and pearls, but it did result in the introduction of other things into Europe, some of which have had very profound effects, though most books of history, more concerned with politics and war than with health and happiness, seldom mention them. Tobacco, corn, potatoes, and very likely syphilis, are some of the outstanding importations for which Europe can thank—or else curse—America. Of the items in this list, the potato is a blessing which has been of more permanent benefit to Europe than even our war loans or the spendings of our tourists. Before the potato—for which the Irish deserve no credit, except for their appreciation of it—was introduced into Europe, scurvy was as common throughout the northern part of that continent as beriberi was in the Orient, and a large proportion of the poorer classes suffered from it in some degree every winter. The "spring fever" of the European peasant was not an exuberance of youthful whims and fancies as now known to us, but was a miserable condition of lethargy, gloom, and irritability, of swollen gums and aching legs, which led the unfortunate sufferers to search for and nibble at the first sprouts and greens to follow the melting snows. Nowadays scurvy is rarely seen in Europe except when there is a failure of the potato crop, as in 1917.

The prevalence of mild scurvy in European peasants has often been overlooked, due to the far greater suffering and untold misery which almost invariably accompanied long sea voyages, military expeditions, or explorations. Scurvy has rightly been called "the plague of the sea and the spoyle of mariners." When Vasco da Gama made his epochal trip around the Cape of Good Hope in 1498, scurvy carried off 100 of his 160 men. There is a record of a Spanish galleon being found adrift at sea with the entire crew dead of this disease.

When Cartier made his second journey to Newfoundland in 1536, he wintered near an Indian Village in Quebec. Of 103 men, 100 were desperately ill with scurvy and 25 died, and this in spite of the most pious prayers and supplications to the Lord. The Indians also suffered. One Indian, however, who had been ill ten or twelve days earlier, was found running about in a state of amazing good health. It developed that he had been browsing on the leaves of a local tree (believed to be a spruce). A decoction was made from these leaves and fed to Cartier's crew. The narrator says of the results: "It wrought so well that if all the physicians of Montpelier and Lausanne had been there with all the drugs of Alexandria they would not have done as much in one year as that tree did in six days, for it did so prevaile that as many as used it by the grace of God recovered their health." The narrator was undoubtedly quite right about the physicians and their drugs, for in that day the juice of citrus fruits was not among the drugs even of Alexandria. In 1734, a ship in the Arctic Sea had on board a man so disabled by scurvy that there was no hope of his recovery and he was set ashore in Greenland with his gums swollen and bleeding, his teeth falling out, his skin dotted with subcutaneous hemorrhages, and his legs so painful

and paralyzed that he was unable to stand. He fed upon a local grass which he plucked with his teeth—and made a perfect recovery.

Vitamin C has been shown to be a carbohydrate acid, for which the name ascorbic acid has been approved. The presence of this substance in fresh fruits was discovered before it was known to have anything to do with the prevention of scurvy, and its presence was put to practical use in distinguishing between fresh and stale fruits, and between natural and artificial fruit juices. It can now be prepared synthetically, and can be tested for by chemical tests delicate enough to detect it in a fraction of a drop of orange juice.

Ascorbic acid is very widely distributed in Nature. Like vitamin B_1 it is concerned with respiration, and is needed by active tissues of both plants and animals. It is found in greatest abundance in the busiest tissues. In plants it is abundant in green parts, especially where there is active growth, and also in fruits and tubers where rapid growth and storage of food materials is taking place, but unlike thiamin it is not stored in seeds or nuts. Thiamin stored in the seeds is all that is necessary to start the process of growth; as soon as germination begins, the young growing plants immediately begin manufacturing ascorbic acid. Any kind of seeds soaked in water for twenty-four hours and then kept in a moist place for a few days till they sprout will become enriched with it. In times of famine when grains, beans, peas, or other seeds might be more readily obtained than fresh vegetables, sprouting these would afford a valuable source of this indispensable vitamin.

In animals the largest amounts of ascorbic acid are found in such active organs as the adrenal glands, liver, brain, etc., and in only small amounts in the muscle meat. Eggs contain practically none, although the developing chicks begin pro-

ducing it as soon as they start their growth. Milk of animals such as cows, which manufacture their own ascorbic acid, contains moderate amounts of this vitamin, even if no fresh fodder containing it is obtained by the animals, but milk of human beings, apes, and guinea pigs, which seem to be the only animals incapable of synthesizing their own vitamin C, varies with the diet. A well-fed human mother has four or five times as much ascorbic acid in her milk as has a well-fed cow, but when she is on a diet deficient in this vitamin, her milk may be almost entirely devoid of it.

One of the richest sources of ascorbic acid is the juice of citrus fruits, especially oranges, lemons, and grapefruit. Next come greens and green vegetables, and then fresh fruits, onions, and potatoes.

There are other points to consider in studying sources of ascorbic acid than the amount of it contained in an ounce of unprepared food. Horse-radish and red peppers have about ten times as much per ounce as have potatoes, yet potatoes are of far greater importance to the human race as a source of vitamins. Fresh green peas, fresh cucumbers, and fresh strawberries are all richer sources of ascorbic acid, ounce for ounce, than are apples or potatoes, but when winter comes the canned peas, strawberry jam, and cucumber pickles are no longer even fair sources of the vitamin, whereas the apples and potatoes stored in the basement, even when boiled, baked, or made into pie, still contain important amounts of it.

Ascorbic acid is a very delicate substance, and must be handled with care. Its outstanding peculiarity is its sensitiveness to oxygen, and when oxidized, other than by a delicate reversible method occurring in the body, it becomes worthless. Heat, and even light, speeds up the process of oxidation, which explains why cooking with exposure to air

is very destructive to it. Even at ordinary room temperatures the vitamin is quickly destroyed in milk, vegetables, etc., exposed to the air, although it is well preserved in bananas, apples, potatoes, etc., in which it is protected by the enclosing skin. Spinach exposed on a market table, even if kept moist and unwilted, loses about half its ascorbic acid in three days and practically all of it in a week, whereas in a refrigerator it hardly deteriorates at all.

Many vegetables and fruits contain an enzyme which, when liberated from the plant cells, greatly hastens the destruction of ascorbic acid. This is why such raw vegetables as spinach, cabbage, turnips, carrots, etc., lose their vitamin very quickly after being crushed, grated, or shredded; they should never be so treated until just before serving, or just before immersion in hot water to kill the enzyme. It is because of the presence of this enzyme that many raw vegetable and fruit juices are practically devoid of the vitamin, whereas others retain it very well. Cider is ordinarily almost entirely lacking in it, even if pressed from apples well supplied with it, whereas orange and tomato juice lose it very slowly.

The loss of vitamin C is accelerated when soda is added to fruits or vegetables when they are cooked, for the vitamin seems to be preserved best at the natural acidity of the substance in which it is found. The housewife's trick of keeping vegetables green or of neutralizing the acidity of tomatoes by adding soda to the cooking water is an invention of the devil, for it greatly hastens the loss of both ascorbic acid and thiamin. Most of us can ill afford such a reckless waste. Another important point is to avoid any copper or copper alloys in cooking vessels or utensils. Even such small amounts of copper as a chemist would have difficulty in detecting may be sufficient to cause almost complete loss of as-

corbic acid during cooking. It is probable that fruits or vegetables sprayed with copper compounds, such as Bordeaux mixture, would lose nearly all of this vitamin when cooked unless very thoroughly washed beforehand.

Still other factors influence the richness of foods in ascorbic acid. Different varieties of apples, potatoes, tomatoes, etc., may vary within several hundred per cent in their ascorbic acid content, and they also vary with their ripeness, the season of the year, and the nature of the soil in which they are grown. Apples, for instance, vary from 0.5 to 3.5 milligrams per ounce; McIntoshes and Delicious are at the lower end of the scale, while Baldwins, Winesaps, and Newtons rank high. In view of the fact that in our northern states apples constitute an important source of ascorbic acid during the winter, it is evident that more attention should be paid to this factor in the development of orchards and the marketing of apples. In all kinds of apples a large part of the vitamin is found in the peelings, so it is fortunate that few people have the obnoxious habit of peeling apples before eating them. Packers of tomatoes and tomato juice should consider the vitamin content of the varieties they use, and distribute only the seeds of varieties rich in vitamins to the farmers who supply the canneries. Soil conditions are also important. Spinach grown on uplands is 50 per cent richer in ascorbic acid than that grown in mucky soil, and fall spinach is richer than summer spinach. Tomatoes, peppers, and fruits increase their ascorbic acid as they ripen, while greens, corn, peas, and snap beans are richest during the period of rapid growth, while still in the tender stage.

Few animal products are important sources of ascorbic acid. Cooked muscle meat contains almost none, although such organs as liver, sweetbreads, brain, etc., may contribute some. In spite of this the great arctic explorer Stefansson

and his friend Anderson proved that not only Eskimos and explorers in the arctic regions, but the same explorers in New York, could live on nothing but meat and fat with no signs of vitamin C deficiency. Possibly fresh meat will be found to contain something that a human being, but not a guinea pig, can convert into ascorbic acid. It is probable that there are varying degrees of efficiency in the manufacture of ascorbic acid in different animals, and man may not be as helpless as guinea pigs. No one has yet found out exactly from what substances animals like rats and cattle make their ascorbic acid, although recently it has been discovered that rats make use of some constituent of certain fats.

Eggs and dairy products, other than fresh milk, are useless as sources of this vitamin. Human milk normally has much larger amounts of ascorbic acid than cow's milk, but varies greatly with the diet. Cow's milk is not a reliable source, and pasteurization destroys a large part of the vitamin C present. Since the advantages of pasteurization of milk far overshadow the disadvantage from loss of an amount of the vitamin, which was not of great importance in the first place, it is the course of wisdom not to rely on milk for this vitamin at all, but to fortify the diet, especially of infants, with orange or tomato juice.

The result of severe and continued deficiency in vitamin C is scurvy, and it was once thought that the vitamin C requirements were taken care of if enough was eaten to prevent this disease. Actually, ascorbic acid plays several important rôles in the body, and scurvy is a late symptom premonitory of death. Its absence is no more a true measure of adequate ascorbic acid than absence of cretinism is a measure of adequate thyroid secretion, or absence of starvation a measure of an adequate economic condition. It was many years after mariners and explorers were saved from scorbutic deaths by

the use of citrus fruits before babies were similarly protected. There was too much emphasis on sterilization and calories, and not enough on vitamins. Pale, fretful, irritable babies with worried expressions, who are in evident pain when they move and cry out when handled, are very likely the victims of a diet of boiled milk and gruel, almost entirely lacking in ascorbic acid. If they have teeth they will also have painful, swollen, bleeding gums. Scurvy in adults is seldom seen any more. It was characterized by painful, aching joints, easily fractured bones, swollen, bleeding gums, a body spotted with burst skin capillaries, a pallid, dirty complexion, a condition of weakness, lethargy, and weariness, and a mind clouded by gloom and inordinate cantankerousness.

In mild vitamin C deficiencies there may be no other symptoms than a tired feeling, a tendency to rheumatic aches, easily broken capillaries, anemia, and a mental apathy and irritability. Ascorbic acid is a magic potion for increasing the joy of living. Some philosopher once aptly remarked how unfortunate it was that so much youth is wasted on the very young. In ascorbic acid we have a precious substance which preserves some of this fleeting youth for later years when it can be more fully appreciated and more advantageously utilized. Since vitamin C deficiency rarely occurs uncontaminated by other deficiencies, it is not always easy to say just how much of the "below-parness" is due to this deficiency.

One of the rôles of ascorbic acid in the body is to help in oxidation processes by acting as a go-between for hydrogen. It plucks hydrogen from one molecule and transfers it to another, and keeps repeating this process over and over. Its function may be compared roughly to that of a truck which carries load after load of sawdust from a lumber mill

to a dumping ground, and thus keeps the mill from burying itself in its own wastes. There are several other substances in the body which perform similar functions in connection with oxidations, and it is possible that to a limited extent this function may be taken over by these other substances when ascorbic acid is not present to the saturation point.

Another important rôle of ascorbic acid is to cause the "ground substance" between the cells of connective and supporting tissues to "set" or "jell." Without ascorbic acid this ground substance remains fluid and lacks "substance" in places where it should be gelatinous or gristly, or where it should be hardened by deposits of lime and phosphorus to form bone, dentine, or enamel. In bones the bone-forming cells first relapse into ordinary connective tissue cells which produce fibrous and gelatinous substances instead of true bone, causing the bones to become weak and easily fractured, and the joints to become enlarged and painful. In severe deficiencies even the fibre and gelatine fail to form. In the teeth a mild deficiency causes the laying down of a defective bone-like material instead of the dense, hard dentine and enamel, and in more severe deficiency the teeth become porous, deformed, and loosened from their sockets. Saturation of the body with ascorbic acid may also protect teeth against decay by assisting in the development of immunity against acidophilus bacilli.

The lens of the eye contains much ascorbic acid, and lack of it is one of the factors concerned in the development of cataracts.

One of the earliest and in all stages the most striking effects of ascorbic acid is on the capillaries. When there is inadequate ascorbic acid, the delicate cells which form the walls of the capillaries are still able to multiply, but no new capillaries form, apparently because the cells fail to form a

cementing substance to bind them together. They are as insubstantial as a wall of bricks without mortar. The existing capillaries become so fragile that they are broken under the slightest strain, and allow blood to ooze out into the surrounding tissue. This may result in anything from pin-head spots to severe hemorrhages, and they may occur in the skin, stomach, intestine, kidneys, or other internal organs. The fragile capillaries are particularly liable to break where there is rubbing, straining, or pressure—where the diaper rubs on babies, where the skin stretches over joints or around teeth in the gums, or where there are bumps or bruises. Nosebleed is common, and there is often blood in the feces and urine.

Another important function of ascorbic acid seems to be the neutralization of various poisons in the body, particularly some produced by infections. It is distinctly protective in such diseases as diphtheria, tuberculosis, infantile paralysis, whooping cough, and rheumatic fever. A recent investigation showed that certain types of disease germs were found five times as frequently in the tonsils of children whose blood was low in ascorbic acid as in children who were well supplied, but in this case it is hard to decide which is the cart and which is the horse. Ascorbic acid is used up in much greater quantities in the presence of certain diseases, and it is just as likely that the tonsil infection depleted the blood of the vitamin as that a low level of the vitamin allowed the germs to get a foothold. Heightened temperature itself greatly increases the amount of ascorbic acid used up, as shown by artificially induced "hot box" fever. The importance of abundant ascorbic acid when the body is ravaged by disease is obvious. It has recently been shown to be the ideal sedative for insomnia resulting from exhaustion of nerves by toxic products of disease.

It has also been observed that ascorbic acid hastens the healing of wounds. It probably does this in at least three different ways—by aiding in the formation of new capillaries, by allowing the formation of fibrous connective tissue, and by neutralizing toxic substances produced by infection. There is even some suspicion that ascorbic acid may be necessary for the formation of new blood cells; at least it has a regulatory function in this connection. This would account for the pallor that is so characteristic of scurvy.

Ascorbic acid also has an important relation to the "complement" of the blood, an enzyme-like substance concerned with immunity. The complement rises and falls with the ascorbic acid, and it is quite possible that the vitamin enters into its composition. Even more important is the demonstration that ascorbic acid stimulates the development of antibodies, by means of which animals react against infections and other invasions of their tissues.

The most recently discovered function of ascorbic acid is that of a protection and a cure for chronic lead poisoning. Lead combines with ascorbic acid in the body so avidly that early symptoms of scurvy may appear in cases of lead poisoning even on a diet which contains considerable amounts of the vitamin. The body apparently suffers partly from lead poisoning and partly from scurvy. If, however, a generous excess of ascorbic acid is provided, the lead is practically all handcuffed to the vitamin and deported with the feces, and an adequate amount of the vitamin is left over for normal use in the body. Evidences of lead poisoning were common among house painters at Oberlin, but four of the painters had unknowingly protected themselves for years by eating a diet unusually rich in ascorbic acid.

Ideas about the amount of ascorbic acid which we need for perfect health have undergone considerable change. Re-

cent dye methods have made it possible to measure the amounts of ascorbic acid in blood, tissues, urine, etc., as well as in foods, so easily that its use in the body, its excretion, etc., can be studied almost as easily as that of sugar. Tests for capillary fragility are now performed to detect actually inadequate amounts of the vitamin, but it is possible that best health is maintained when the daily ascorbic acid intake is considerably greater, so that the tissues are saturated with it. Under these conditions about a third of the amount eaten is excreted in the urine, but if the saturation point is passed, practically all of the excess is excreted. It has not been proved that it is necessary to maintain this saturated state, but it certainly does no harm, and it provides a good margin of safety in emergencies. Unusually large amounts are needed by the body not only in the presence of various infectious diseases and other types of poisoning, but also when the rate of living is speeded up by an over-active thyroid, fever, high protein diet, or other causes. Sometimes, also, unusually large amounts are lost, especially when we do some good serious sweating. The Bantu laborers in South African gold mines, for instance, may lose as much as five pounds in weight during an eight-hour shift underground, most of it in sweat. The sweat contains so much ascorbic acid that at this rate they lose about 2 milligrams per hour in *addition* to the normal loss in the urine. Children, and especially babies, who have a higher rate of metabolism than adults, need more ascorbic acid in proportion to their weight than do their elders.

The most recent estimates of the daily amount of ascorbic acid needed for perfect health, and with a good margin of safety, lies between 30 and 60 milligrams for adults, and about half that for babies, with intermediate amounts for children, depending upon their age and activity. Some

writers set barely adequate amounts at about 20 or even 40 milligrams for babies, 40 for children, and 50 or 60 for adults, but the apparent good health of large groups of people who do not get this much makes it doubtful whether an intake of ascorbic acid to the saturation point is really needed, except possibly for expectant and nursing mothers. Recent estimates for pregnant women run as high as 75-125 mg., and for nursing women 100 to 150 mg. (=5 to 8 oz. of orange juice) per day.

An idea of the food necessary to provide us with our daily ascorbic acid can be obtained from the following table of approximate milligrams per ounce (milk per pint):

Citrus fruit juice	18-20 mg.
Tomatoes or tomato juice	8-10 mg.
Greens properly cooked	5-10 mg.
Raw green peppers	50 mg.
Fresh raw vegetables	5-10 mg.
Cooked fresh or canned vegetables	2-5 mg.
Potatoes, properly cooked	3-5 mg.
Pineapple and strawberries, fresh	8 mg.
Pineapple, canned or juice	3 mg.
Apples and most other fruits	0.5-3.5 mg.
Pasteurized milk, per pint	3-6 mg.

All the abnormal conditions of bones, teeth, joints, capillaries, and disposition due to lack of ascorbic acid are improved within a few hours after the vitamin is provided. Scurvy responds to it as magically as neuritis does to thiamin, or pellagra to nicotinic acid. Pure ascorbic acid is now available in crystalline or tablet form, but it must not be dissolved until immediately before use or it will deteriorate. Apparently no harmful effects result from the continued use of large doses, even up to 500 milligrams per day. When

the ascorbic acid reaches a certain concentration in the blood, the kidneys eliminate it, apparently without the least difficulty. The capillaries show improved resistance to breaking within a few hours after a dose of ascorbic acid, and very sick babies show remarkable improvement in one or two days. The bone and tooth injuries take longer to repair, and in severe scurvy overdoses of the vitamin should be provided for several weeks.